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## **Climate of South and Southeast Asia according to Thornthwaite's Classification Scheme**

by

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### **Introduction**

In the course of the study of the paddy soils in South and Southeast Asia (Project Leader: Prof. K. Kawaguchi, Faculty of Agriculture, Kyoto University) there are many instances where soil distribution is governed primarily by climate. The occurrence of Grumusols in a region that has a distinctly dry season is an oft-quoted examples of this sort. One of the most striking examples of differing soil distribution governed by climate is seen in Ceylon. Irrespective of the similarity of parent rocks underlying a greater part of the island, Reddish Brown Earths are the dominant soils in the dry zone as against associations of Red-Yellow Podzolic Soils and Red-Yellow Latosols in the wet zone. Thus, in attempting to acquire a better understanding of soil forming conditions over the entire paddy-growing area of tropical and subtropical Asia, climate must first be made the subject of a detailed study.

There are several schemes for classifying world climates, the one proposed by Köppen being the most well known. A method proposed by Thornthwaite (1) in 1948 is also widely used and has unique features in that 1) water need is computed from mean monthly temperature as "potential evapotranspiration", and 2) soil moisture retention is taken into consideration in assessing water surplus and deficiency. As "soil-forming processes are related to water surpluses and deficiencies" (estimated with due consideration for soil moisture), Thornthwaite's method has been preferred to other classification schemes by many soil scientists. For this reason, we apply the same method to the present study, in spite of the intrinsic questions as to method which are discussed below.

### **Data and Methods**

The regions studied in this paper are restricted to those in which rice is an important agricultural crop. Thus, a part of India, i. e., Kashmir, Rajasthan and Gujarat, as well as a wide area extending beyond the Indus Plain in West Pakistan are deliberately

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omitted from the study area.\*

The necessary data for making the classifications, i.e., mean monthly temperature and rainfall, were obtained from different sources as listed below for each country or region.

Pakistan (West and East)	Reference (2)
India	Ditto
Ceylon	Ditto
Burma	Ditto
Laos	Ditto
Cambodia	Ditto
Vietnam (North and South)	Ditto
Philippines	Ditto
East Malaysia	Ditto
West Malaysia	Reference (2) & (3)
Indonesia	Reference (2), (4), (5) & (6)
Thailand	Reference (7)

For Thailand, not only the data but also various indices according to Thornthwaite's method were cited from Ogino (7), who had adopted the same method to classify the climate of Thailand.

The accuracy of the data cited from the above sources is quite variable. The length of time over which these meteorological data were accumulated varies from periods as short as one or two years to greater than fifty years. The density of distribution of the meteorological stations, as seen in Figs. 1-7, is also quite variable from one region to another. This affects accuracy in the mapping of results.

The range of longitude, latitude, and altitude of the two hundred seventy-eight stations for which data are available have the following spreads:

Longitude	66°59'E	128°10'E
Latitude	10°10'S	32°30'N
Altitude	0 m	3,023 m

The basic parameter in Thornthwaite's method is "potential evapotranspiration (PE)". According to Thornthwaite the value of PE ( $e$  cm) is related to a mean monthly temperature ( $\theta^\circ\text{C}$ ) by the following formula:

$$e = c\theta^a$$

where  $c$  and  $a$  are functions of  $\theta$ . Empirically  $a$  is expressed by a formula,

$$a = 675 \times 10^{-9} I^3 - 771 \times 10^{-7} I^2 + 1792 \times 10^{-5} I + 0.49239$$

\* Even the Indus Plain is not a rice-growing area in its natural climatic condition. But with its developed irrigation system, the area under rice cultivation is presently about 1.3 million hectares (3.25 million acres), which exceeds the sum of all rice growing areas in West Malaysia and Ceylon.

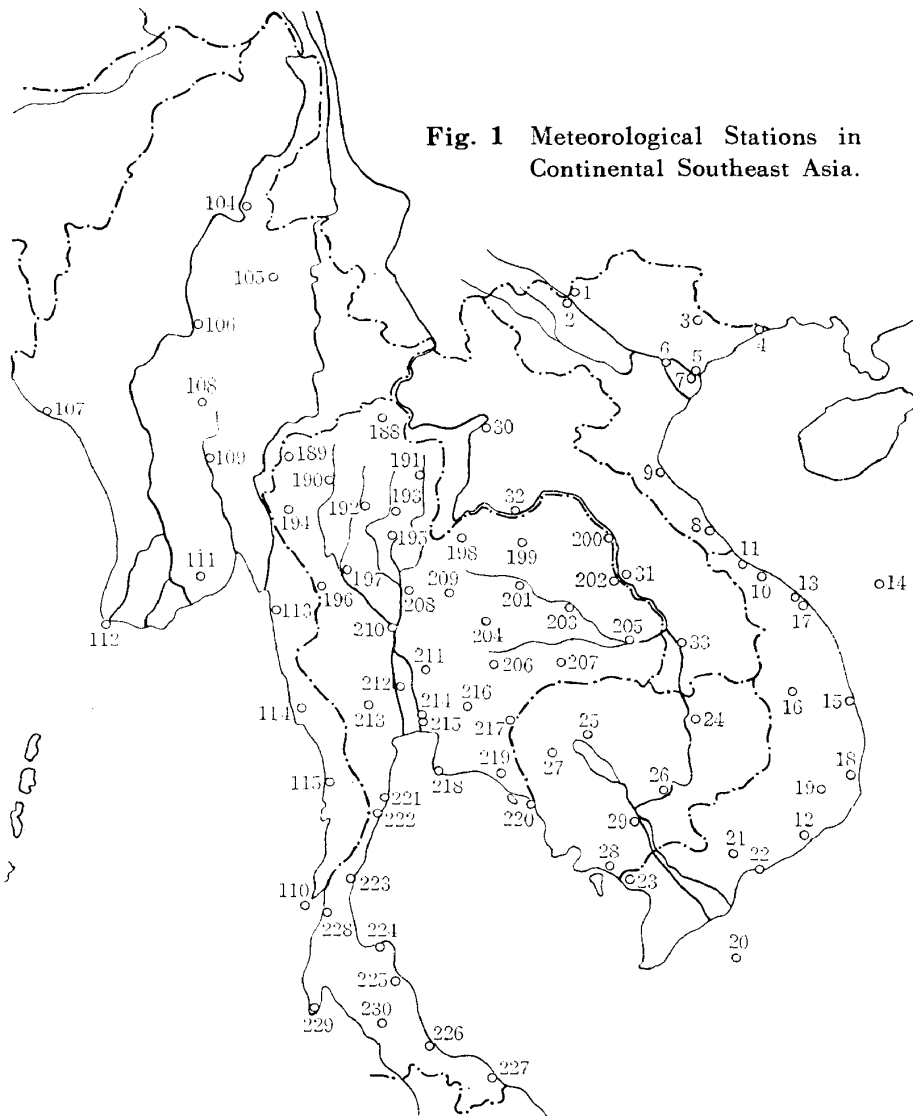


Fig. 1 Meteorological Stations in Continental Southeast Asia.

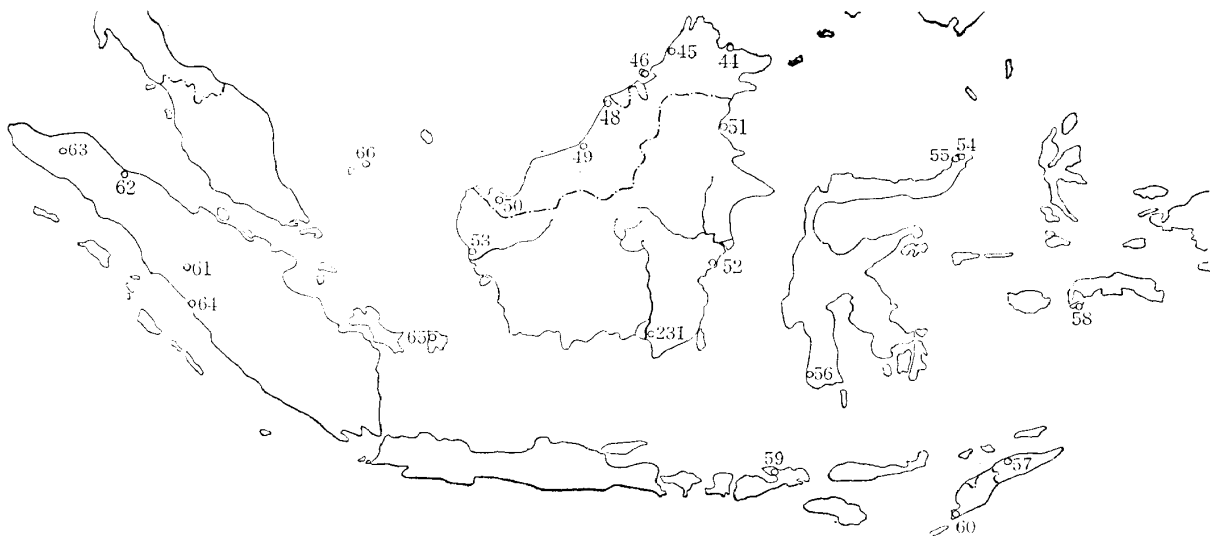


Fig. 2 Meteorological Stations in Insular Southeast Asia.

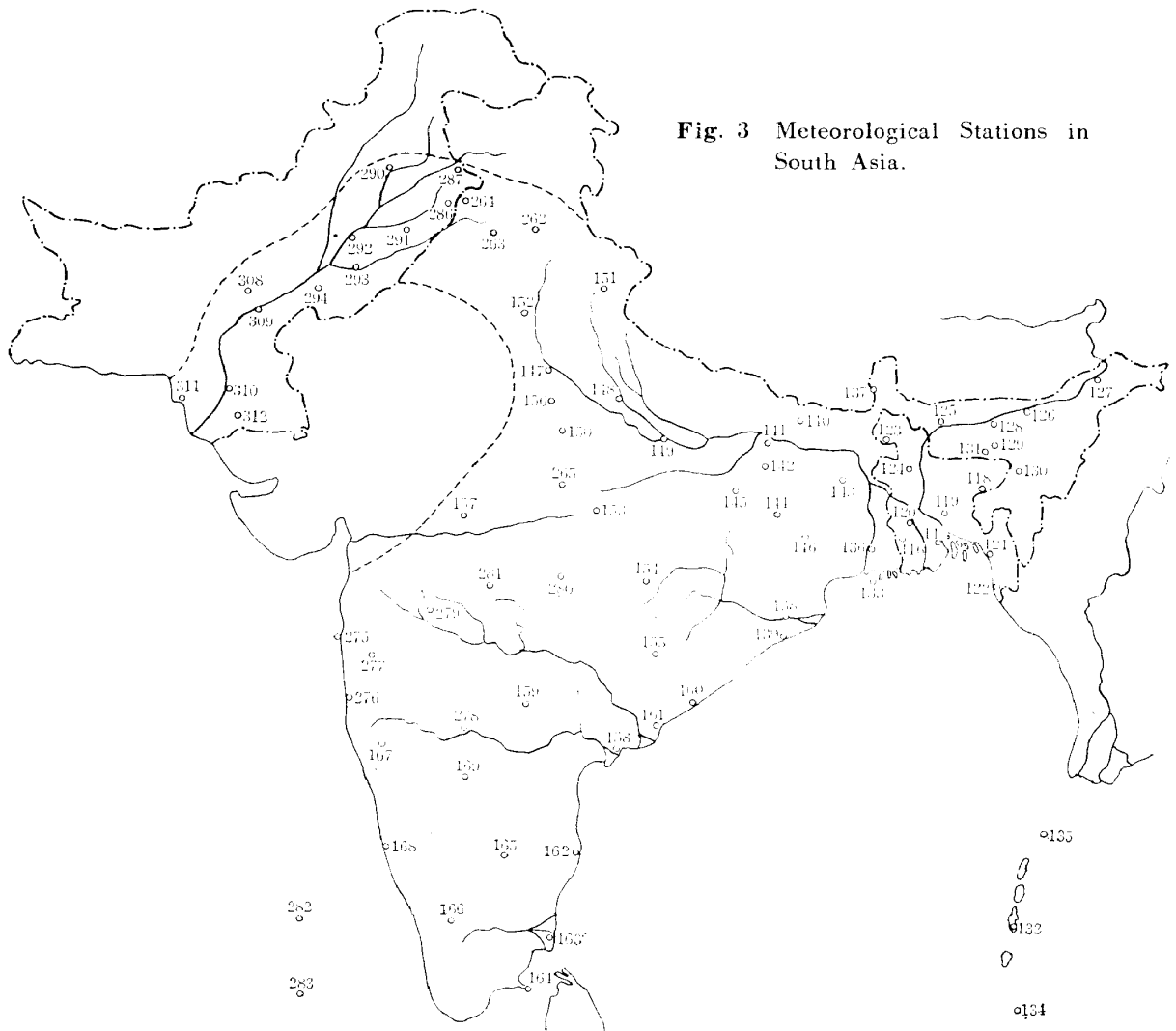


Fig. 3 Meteorological Stations in South Asia.

where

$$I = \sum_{i=1}^{12} i, \text{ and } i = (\theta/5)^{1.514}$$

In effect,  $e$  is expressed as follows,

$$e = 1.6(10\theta/I)^a$$

Thornthwaite prepared a table of  $i$  values for different  $\theta$  to save the labor of calculation. Computation of  $e$  from the values of  $I$  and  $\theta$  according to the formula is also facilitated by the use of a nomogram, a basic assumption for which is that a straight line relationship between  $\log \theta$  and  $\log e$  always passes a point corresponding to  $\theta = 26.5^\circ\text{C}$  and  $e = 13.5 \text{ cm}$  in a  $\log \theta$  vs.  $\log e$  coordinate. For temperatures higher than  $26.5^\circ\text{C}$ , values of  $e$  cannot be computed with the Thornthwaite formula, but are given in a separate table. Since  $e$  values thus obtained are standard values for a day length of 12 hours and for a 30-day month, corrections for actual day lengths and actual total monthly days are necessary. Correction factors are also given in another table for different

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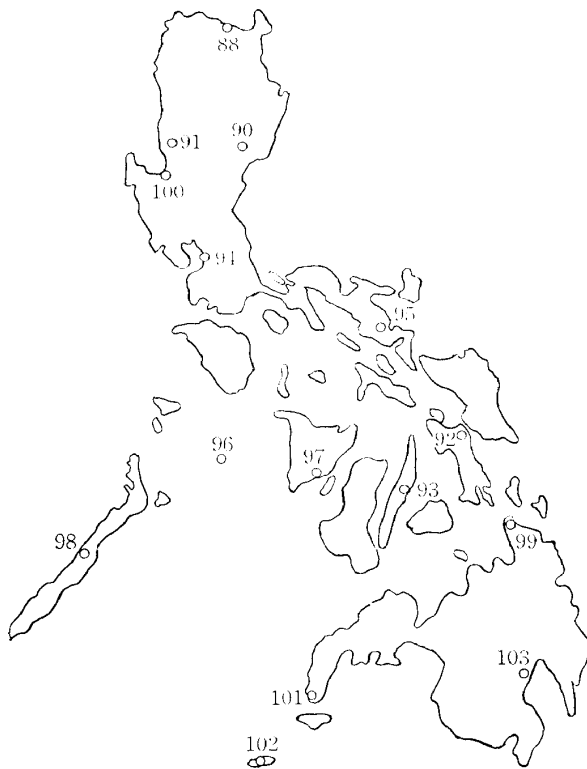


Fig. 4 Meteorological Stations in the Philippines.

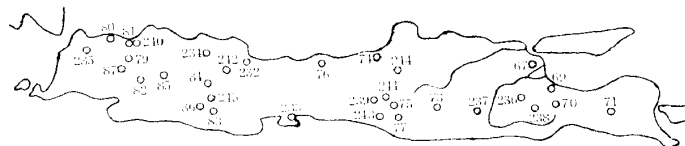


Fig. 5 Meteorological Stations in Java, Indonesia.

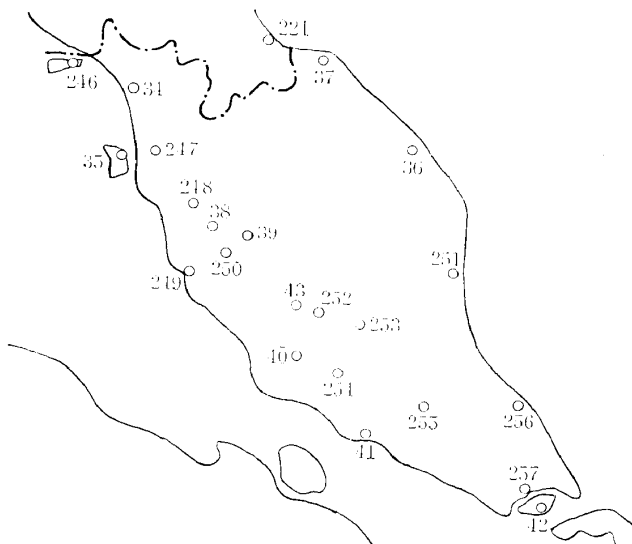


Fig. 6 Meteorological Stations in West Malaysia and Singapore.

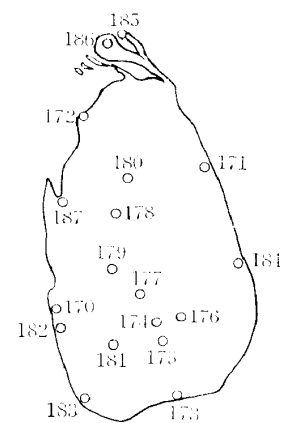


Fig. 7 Meteorological Stations in Ceylon.

latitudes and months.

Even using the nomogram and the tables, the computation of a corrected PE value requires considerable time and labor. In the present paper this process is left to a computer (FACOM 230-60 of the Computer Center of Kyoto University) by feeding the tables into its memory core and by transforming the nomogram into formulae. Direct computation using the Thornthwaite formula has also been attempted, but the deviation of the result from that of the tables-and-nomogram method is especially large when temperatures are higher than 26.5°C.

Given the data for water requirement (i. e., potential evapotranspiration) and water supply (i. e., rainfall), the water balance for each month can be estimated. In this process a moisture retention maximum of 100 mm is postulated for every soil regardless of its texture. Though this assumption is often criticized, for the purposes of climatic classification no better alternative can be proposed in view of the wide variability of soil texture even within a similar climatic region. By summing up monthly surpluses and deficiencies, yearly values  $s$  and  $d$ , respectively, are obtained. Using  $e(\text{PE})$ ,  $s$ , and  $d$  values the following three indices are calculated :

$$\begin{aligned}\text{Humidity index} \quad I_h &= \frac{100s}{e} \\ \text{Aridity index} \quad I_d &= \frac{100d}{e} \\ \text{Moisture index} \quad I_m &= \frac{100s - 60d}{e}\end{aligned}$$

The following climatic types are distinguished according to their moisture index values :

Climatic Type	Moisture Index
A Perhumid	100 and above
B <sub>4</sub> Humid	80 to 100
B <sub>3</sub> Humid	60 to 80
B <sub>2</sub> Humid	40 to 60
B <sub>1</sub> Humid	20 to 40
C <sub>2</sub> Moist Subhumid	0 to 20
C <sub>1</sub> Dry Subhumid	-20 to 0
D Semiarid	-40 to -20
E Arid	-60 to -40

Furthermore, moist climates (A, B, C<sub>2</sub>) and dry climates (C<sub>1</sub>, D, E) are subdivided as follows according to their aridity and humidity indices :

Moist Climates (A, B, C <sub>2</sub> )	Aridity Index
r little or no water deficiency	0-16.7
s moderate summer water deficiency	16.7-33.3
w moderate winter water deficiency	16.7-33.3

s <sub>2</sub> large summer water deficiency	33.3+
w <sub>2</sub> large winter water deficiency	33.3+
Dry Climates (C <sub>1</sub> , D, E)	Humidity Index
d little or no water surplus	0-10
s moderate winter water surplus	10-20
w moderate summer water surplus	10-20
s <sub>2</sub> large winter water surplus	20+
w <sub>2</sub> large summer water surplus	20+

As for the thermal regime, PE itself is used as an index of thermal efficiency. Different climatic types are separated as follows:

Climatic Type	TE Index (or PE)
E' Frost	14.2 (cm) and below
D' Tundra	28.5-14.2
C <sub>1</sub> ' Microthermal	42.7-28.5
C <sub>2</sub> ' Microthermal	57.0-42.7
B <sub>1</sub> ' Mesothermal	71.2-57.0
B <sub>2</sub> ' Mesothermal	85.5-71.2
B <sub>3</sub> ' Mesothermal	99.7-85.5
B <sub>4</sub> ' Mesothermal	114.0-99.7
A' Megathermal	114.0 and above

In addition to this, summer concentration of thermal efficiency (S) is taken as another differentiating characteristic. S is a measure of the concentration of potential evapotranspiration over the three-month summer period expressed as a percentage of total PE. Summer concentration types are separated as follows:

Summer Concentration Types	Summer Concentration %
a'	48.0 and below
b <sub>4</sub> '	51.9-48.0
b <sub>3</sub> '	56.3-51.9
b <sub>2</sub> '	61.6-56.3
b <sub>1</sub> '	68.0-61.6
c <sub>2</sub> '	76.3-68.0
c <sub>1</sub> '	88.0-76.3
d'	88.0 and above

The method of computation and the criteria for classification for this study having been outlined above, before stating the result of their application, we have to admit one fundamental drawback to the method when applied to a tropical climate. Though Thornthwaite's method is apparently intended to cover the tropics, there is no guarantee



for its validity when actually applied there. As Thornthwaite himself noted, "the computed values of potential evapotranspiration are of the right order of magnitude throughout most of the United States, but whether or not the formula can be used without modification to determine PE in equatorial regions is uncertain."

In this study the fourth differentia, i. e., summer concentration of thermal efficiency, is not taken into account, because the regions here studied are mostly tropical and such summer concentration is not very much in evidence. Thus, the first three criteria, that is, the moisture index, the thermal efficiency index, and the aridity or humidity index, are used for making the climatic classification.

In subdividing moist and dry climates according to their aridity or humidity indices, the six months from May to October are taken as summer and the remaining six months as winter. This division coincides with the customary division of rainy and dry seasons for most of the area studied.

### Results and Discussions

The results of computations and classification are given in Tables 1 to 11 for each country or region. The location of meteorological stations is plotted in Figures 1 to 7. To summarize the study, an approximate distribution of different climatic types in terms of moisture index values and the seasonal distribution of water surplus and deficiency is shown in Figure 8.

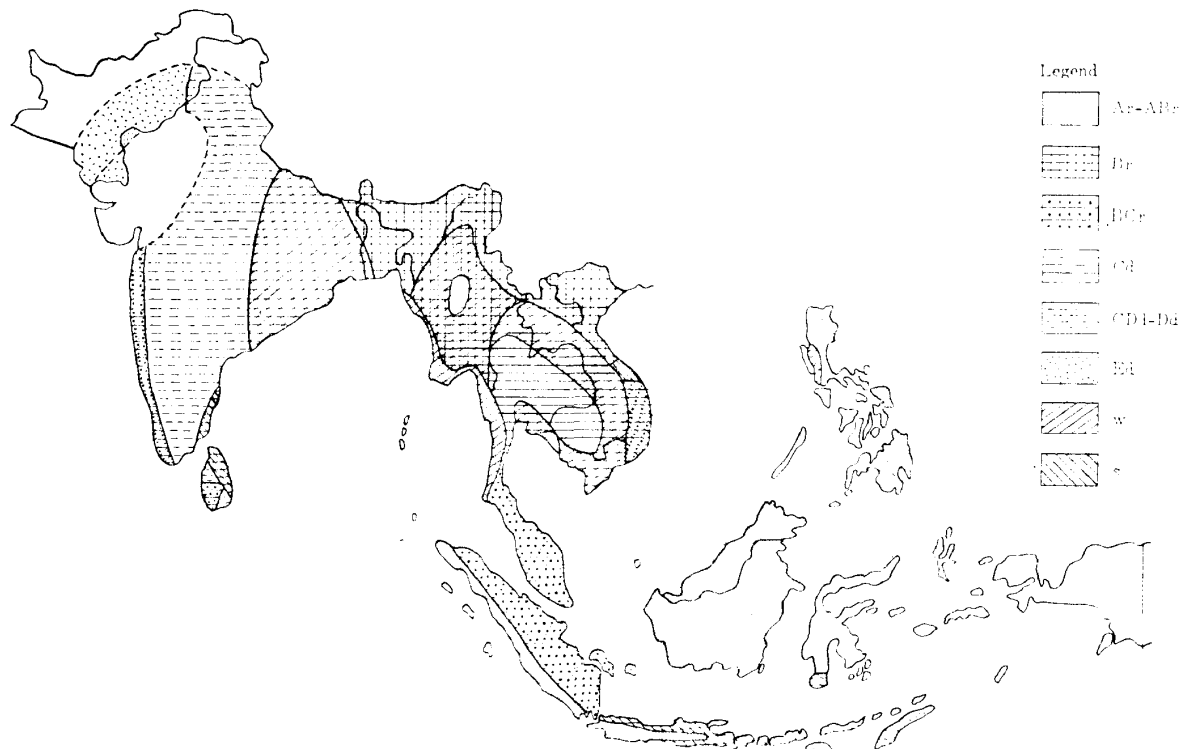


Fig. 8 Climatic Regions in South and Southeast Asia with Respect to Humidity and Seasonal Distribution of Water Surplus or Deficiency.

According to their thermal efficiency indices, most of the stations within the area belong to the megathermal class or A'. Only those stations situated at high altitudes belong to mesothermal classes, B<sub>4</sub>'-B<sub>1</sub>'. The following generalization can be made as to the relationship between thermal efficiency class and altitude :

Thermal Efficiency Class	Altitude	No. of Stations
A'	Below 500 m	—
B <sub>4</sub> '	500-900	5
B <sub>3</sub> '	900-1300	8
B <sub>2</sub> '	1300-2000	11
B <sub>1</sub> '	Above 2000	4

Notable exceptions to the rule are as follows :

Class	Station No.	Altitude
A'	144	655
	155	553
	157	556
	159	545
	165	921
	167	753
	176	667
	265	551
	277	559
	279	581
B <sub>4</sub> '	3	265
B <sub>2</sub> '	19	962

All but one (No. 176) of the exceptions to class A' are from the inland part of India, where summer concentration of thermal efficiency is relatively high and a continental climate prevails. Station No. 3 is located along the China-Vietnam border and the irregularity may be related to a high latitude. For Station No. 19 in South Vietnam no reasonable explanation is available.

Generalizations in terms of humidity climatic types are more difficult to draw and the delineation of climatic classes on even a small-scale map requires some boldness. Some of the noteworthy points that the author has found are as follows :

(1) The distribution of perhumid to fourth humid climates (A or B<sub>4</sub>) is relatively narrow on lowlands. This is in contrast to a wide area of Tropical Rainforest climate in Köppen's classification. For example, a greater part of the west coast lowland of West Malaysia belongs to the Tropical Rainforest climate area in Köppen's scheme, whereas here the same area is shown to have mainly subhumid to first humid climate (C<sub>2</sub> or B<sub>1</sub>).

(2) The continental part of Thailand and Cambodia is the driest area of considerable extension in Southeast Asia, almost as dry as the Ganges basin of India or the dry zone of Ceylon in South Asia. There is a general impression that Southeast Asia is a humid region as contrasted to South Asia where climate is much drier. But this is not necessarily the case. The occurrence of Grumusols in Thailand and Cambodia can now be readily explained on a climatic basis.

(3) Fairly obviously, orographic influence on the distribution of humidity climatic types is great. A typical example of this is seen in the spotty occurrence of perhumid to fourth humid areas in the southeastern coastal part of Thailand, where mountain ranges over 1500 meters high act as a barrier to the moist air coming from the Gulf of Thailand.

(4) With respect to the seasonal distribution of water surplus or deficiency, the study area can be grouped into the following four categories:

Moist throughout (r)---North Vietnam, Assam (India), West Malaysia, Sumatra, Borneo (Kalimantan and East Malaysia), the inland part of Java, East Pakistan, the Ceylon wet zone, and the greater part of the Philippines.

Summer rain (w)---Marginal parts of Thailand and Cambodia, Laos, South Vietnam, Burma, the east coast of the Bay of Bengal, the Arabian Sea coast of India, and northeastern India.

Winter rain (s)---Middle Vietnam, the Java Sea coast, the Ceylon dry zone, and the southeastern coast of India.

Dry throughout (d)---The central areas of Thailand, Cambodia, and Burma, central and northwestern India, and West Pakistan.

By way of summary, a map (Fig. 8) was prepared showing humidity climatic types and the seasonal distribution of water surplus and deficiency over the study area (low-land). Although we have to admit numerous inclusions for each of the climatic types delineated on the map, we are able to assess the degree of dessiccation or moistening that a soil undergoes during its formation process in different regions of South and Southeast Asia.

### Summary

As a first step towards clarifying the soil-forming conditions of rice-growing tropical and subtropical Asia, a climatic classification according to Thornthwaite's method was carried out. Data on the mean monthly temperature and rainfall for some 280 meteorological stations throughout most of the South and Southeast Asian regions were collected from various sources. Computation of the potential evapotranspiration was facilitated by the use of a computer. Classification results are expressed by a combination of 3 symbols representing humidity, thermal efficiency, and the seasonal distribution of water

surplus or deficiency. Thus, forty-two climatic types are distinguished in the study area. A generalization as to the relationship between altitude and climatic type was deduced with respect to thermal efficiency. Distribution of the humidity climatic types was so complex that only a small-scale map with many inclusions could be prepared (cf. Fig. 8).

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Table 1 Moisture Data for VIETNAM

(in mm)

Station		Latitude	Altitude m	Water need (PE or TE)	Precipi- tation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
No.	Name								
(North Vietnam)									
1	Laokay	22°30'N	103	1231	1750	519	0	42.2	B <sub>2</sub> A'r
2	Chapa	22°21'N	1640	750	2768	2019	0	269.1	(AB <sub>2</sub> 'r)
3	Langson	21°51'N	265	1116	1428	312	0	28.0	B <sub>1</sub> B <sub>4</sub> 'r
4	Moncay	21°31'N	10	1216	3085	1869	0	153.7	AA'r
5	Haiphong	20°49'N	5	1296	1774	521	43	38.2	B <sub>1</sub> A'r
6	Hanoi	21°30'N	8	1256	1673	423	5	33.4	B <sub>1</sub> A'r
7	Phulien	20°40'N	113	1232	1781	551	0	44.7	B <sub>2</sub> A'r
8	Dong Hoi	17°29'N	20	1388	2118	1059	331	62.0	B <sub>3</sub> A's
9	Vinh	18°39'N	6	1286	1828	630	88	44.9	B <sub>2</sub> A'r
(South Vietnam)									
10	Hue	16°24'N	16	1351	2904	1790	237	122.0	AA's
11	Quang Tri	16°44'N	7	1423	2541	1445	326	87.8	B <sub>4</sub> A's
12	Phanthiet	10°56'N	6	1623	1216	130	537	— 11.8	C <sub>1</sub> A'd
13	Tourane	16° N	8	1435	1974	1027	487	51.2	B <sub>2</sub> A's <sub>2</sub>
14	Hoang-Sa	16°33'N	6	1638	1348	189	478	— 6.0	C <sub>1</sub> A's
15	Qui Nhou	13°45'N	6	1567	1653	711	625	21.4	B <sub>1</sub> A's <sub>2</sub>
16	Pleiku	13°59'N	779	1021	2684	1847	182	170.2	(AB <sub>4</sub> 'w)
17	Da Nang	16°02'N	7	1470	1969	949	450	46.2	B <sub>2</sub> A's
18	Nha-Trang	12°15'N	6	1590	1096	231	727	— 12.9	C <sub>1</sub> A's
19	Dalat	11°45'N	962	837	1804	975	9	115.9	(AB <sub>2</sub> 'r)
20	Poulo Condore	8°40'N	6	1686	1834	567	418	18.8	C <sub>2</sub> A'w
21	Saigon	10°47'N	11	1685	1806	560	440	17.57	C <sub>2</sub> A'w
22	Cape Saint Jacques	10°20'N	18	1579	1300	204	484	— 5.5	C <sub>1</sub> A'w
23	Hatien	10°10'N	3	1689	1958	572	302	23.1	B <sub>1</sub> A'w

Table 2 Moisture Data for CAMBODIA

No.	Station	Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
	Name								
24	Stung Treng	13°31'N	54	1625	1729	565	460	17.8	C <sub>2</sub> A'w
25	Siemreap	13°22'N	15	1616	1281	202	537	— 7.4	C <sub>1</sub> A'w
26	Kompong Cham	12°00'N	16	1690	1698	472	463	11.5	C <sub>2</sub> A'w
27	Battambang	13°06'N	18	1665	1350	104	419	— 8.9	C <sub>1</sub> A'd
28	Kampt	10°37'N	5	1703	2066	624	258	27.5	B <sub>1</sub> A'r
29	Phnom Penh	11°33'N	12	1750	1320	92	523	— 12.7	C <sub>1</sub> A'd

Table 3 Moisture Data for LAOS

30	Luang Prabang	19°53'N	304	1453	1203	50	300	— 8.9	C <sub>1</sub> A'd
31	Seno Savannakhet	16°33'N	155	1532	1460	383	457	7.1	C <sub>2</sub> A'w
32	Vientiane	17°57'N	170	1535	1714	578	400	22.0	B <sub>1</sub> A'w
33	Pakse	15°07'N	96	1673	1564	526	635	8.7	C <sub>2</sub> A'w <sub>2</sub>

Table 4 Moisture Data for MALAYSIA  
(West Malaysia)

34	Alor Star Aevodrone	6°12'N	3	1714	2128	615	201	28.8	B <sub>1</sub> A'r
35	Penang	5°25'N	5	1772	2733	987	26	54.8	B <sub>2</sub> A'r
36	Kuala Trengganu	5°20'N	31	1735	2912	1177	0	67.8	B <sub>3</sub> A'r
37	Kota Bharu	6°08'N	6	1688	2755	1138	72	63.4	B <sub>3</sub> A'r
38	Ipoh	4°34'N	39	1687	2348	663	0	39.3	B <sub>1</sub> A'r
39	Comeron Highlands	4°28'N	1448	810	2642	1833	0	226.3	(AB <sub>2</sub> 'r)
40	Kuala Lumpur	3°07'N	39	1720	2499	779	0	45.3	B <sub>2</sub> A'r
41	Malacca	2°12'N	45	1692	2207	516	0	30.5	B <sub>1</sub> A'r
42	Singapore	1°18'N	10	1716	2232	516	0	30.1	B <sub>1</sub> A'r
43	Frasers Hill	3°43'N	1301	886	2719	1835	0	207.2	(AB <sub>3</sub> 'r)
246	P. Langkawi	6°19'N	4	1660	2462	978	175	52.6	B <sub>2</sub> A'r
247	Kulim	5°23'N	32	1730	3128	1399	0	80.9	B <sub>4</sub> A'r

No.	Station Name	Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
248	Kualakangsar	4°46'N	39	1740	2043	324	21	17.9	C <sub>2</sub> A'r
249	Sitiawan	4°13'N	7	1710	1902	296	106	13.6	C <sub>2</sub> A'r
250	Kampar	4°18'N	39	1724	3686	1961	0	113.7	AA'r
251	Kuantan	3°46'N	19	1589	3003	1414	0	89.0	B <sub>4</sub> A'r
252	Bentong	3°31'N	97	1746	2354	610	0	34.9	B <sub>1</sub> A'r
253	Kepong	3°14'N	97	1665	2693	1027	0	61.7	B <sub>3</sub> A'r
254	Jelevu	2°57'N	137	1633	1661	107	80	3.6	C <sub>2</sub> A'r
255	Segamat	2°30'N	29	1742	1991	258	10	14.5	C <sub>2</sub> A'r
256	Mersing	2°27'N	45	1547	2822	1276	0	82.5	B <sub>4</sub> A'r
257	Johore Bahru	1°28'N	15	1694	2815	1123	0	66.3	B <sub>3</sub> A'r
(East Malaysia)									
44	Sandakan	5°50'N	46	1773	3137	1364	0	76.9	B <sub>3</sub> A'r
45	Jesselton	5°51'N	3	1627	2591	1197	234	64.9	B <sub>3</sub> A'r
46	Labuan	5°17'N	18	1772	3573	1803	0	101.8	AA'r
48	Miri	4°23'N	3	1680	2834	1153	0	68.6	B <sub>3</sub> A'r
49	Bintula	3°11'N	3	1587	3499	1914	0	120.6	AA'r
50	Kuching	1°29'N	26	1693	3905	2214	0	130.8	AA'r
<b>Table 5</b> Moisture Data for INDONESIA									
51	Tarakan	3°19'N	12	1613	3869	2257	0	140.0	AA'r
52	Balikpapan	1°17'N	7	1579	2228	649	0	41.1	B <sub>2</sub> A'r
53	Pontianak	0°01'N	3	1698	3178	1481	0	87.2	B <sub>4</sub> A'r
54	Mapanget	1°32'N	86	1395	3398	2002	0	143.5	AA'r
55	Menado	1°30'N	2	1582	2663	1116	36	69.2	B <sub>3</sub> A'r
56	Makassar	5°08'S	2	1600	2851	1685	435	89.0	B <sub>4</sub> A's
57	Dili	8°35'S	0	1785	848	0	— 938	— 31.5	DA'd
58	Amboina	3°42'N	4	1567	3459	1892	0	120.7	AA'r
59	Tambora	8°12'S	500	1053	3752	2698	0	256.2	(AB <sub>4</sub> 'r)

Station		Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
No.	Name								
60	Koepang	10°10'S	45	1647	1440	542	749	5.6	C <sub>2</sub> A's <sub>2</sub>
61	Fort de kock	0°18'N	920	994	2105	1113	0	111.9	(AB <sub>3</sub> 'r)
62	Medan	3°35'N	23	1516	2029	512	0	33.8	B <sub>1</sub> A'r
63	Takengon	4°40'N	1205	964	1738	775	0	80.4	(B <sub>4</sub> B <sub>3</sub> 'r)
64	Padang	0°56'S	7	1626	4172	2547	0	156.6	AA'r
65	Tandjueng Pandan	2°45'S	3	1637	2874	1238	0	75.6	B <sub>3</sub> A'r
66	Terempa	3°12'N	3	1639	2403	764	0	46.6	B <sub>2</sub> A'r
67	Soerabaya	7°16'S	7	1670	1674	439	436	10.6	C <sub>2</sub> A's
69	Pasuruan	7°38'S	5	1684	1284	191	591	— 9.7	C <sub>1</sub> A's
70	Tosari	7°58'S	1735	744	2018	1292	18	172.1	(AB <sub>2</sub> 'r)
71	Djember	8°09'S	83	1461	1868	595	187	33.0	B <sub>1</sub> A'r
73	Tawang Mangoe	7°37'S	952	896	3369	2523	48	278.4	(AB <sub>3</sub> 'r)
74	Semarang	7°00'S	10	1643	2033	519	129	26.6	B <sub>1</sub> A'r
75	Klaten	7°42'S	200	1537	1639	502	400	17.1	C <sub>2</sub> A's
76	Pekalongan	6°53'S	9	1637	2213	788	211	40.4	B <sub>2</sub> A'r
77	Wedi-Birit	7°45'S	150	1519	1846	582	254	28.3	B <sub>1</sub> A's
79	Tjitajam	6°27'S	110	1546	3466	1920	0	124.2	AA'r
80	Kuyper	6°02'S	2	1791	1603	276	464	— 0.1	C <sub>1</sub> A's
81	Jakarta	6°11'N	8	1638	1799	424	263	16.3	C <sub>2</sub> A'r
82	Pangerango	6°45'S	3023	585	3286	2701	0	461.9	(AB <sub>1</sub> 'r)
83	Kertasari	7°14'S	1620	746	2663	1917	0	257.0	(AB <sub>2</sub> 'r)
84	Lembang	6°50'S	1300	849	1946	1098	0	129.3	(AB <sub>2</sub> 'r)
85	Patjet	6°45'S		872	2736	1865	0	214.0	(AB <sub>3</sub> 'r)
86	Tjiwidej Bosch keet	7°10'S	1780	736	3445	2709	0	368.3	(AB <sub>2</sub> 'r)
87	Buitenzorg (Bogor)	6°35'S	250	1385	3934	2550	0	184.1	AA'r
231	Bandjarmasin	3°19'S	2	1678	2755	1077	0	64.2	B <sub>3</sub> A'r
232	Tjirebon	6°42'S	4	1809	2209	723	324	29.2	B <sub>1</sub> A's
233	Tjilatjap	7°44'S	6	1614	4274	2659	0	164.8	AA'r



No.	Station Name	Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
234	Subang	6°35'S	95	1539	3369	1855	26	119.5	AA'r
235	Serang	6°07'S	40	1666	1739	225	152	8.0	C <sub>2</sub> A'r
236	Punteu (Batu)	7°50'S	1000	942	1847	962	56	98.6	(B <sub>4</sub> B <sub>3</sub> 'r)
237	Modjopanggung	8°03'S	90	1644	1893	489	241	21.0	B <sub>1</sub> A'r
238	Malang	7°58'S	445	1192	2193	1073	71	86.5	B <sub>4</sub> A'r
239	Magelang	7°29'S	380	1324	2804	1479	0	111.7	AA'r
240	Kemajoran	6°08'S	3	1601	1719	362	244	13.5	C <sub>2</sub> A'r
241	Kaliurang	7°36'S	925	962	4875	3913	0	406.8	(AB <sub>3</sub> 'r)
242	Kadhipaten	6°46'S	45	1713	3114	1581	181	86.0	B <sub>4</sub> A'r
243	Djakarta	7°49'S	—	1507	2002	643	147	36.8	B <sub>1</sub> A'r
244	Dadapajam	7°17'S	172	1657	2896	1297	57	76.2	B <sub>3</sub> A'r
245	Baudung	6°55'S	768	1100	2159	1060	0	96.4	(B <sub>4</sub> B' <sub>4r</sub> )

Table 6 Moisture Data for THE PHILIPPINES

88	Aparri	18°22'N	4	1657	2307	916	266	45.6	B <sub>2</sub> A'r
89	Basco	20°27'N	11	1557	3003	1446	0	92.9	B <sub>4</sub> A'r
90	Echague	16°42'N	78	1667	1583	279	365	3.6	C <sub>2</sub> A's
91	Baguio	16°25'N	1510	811	4615	3804	0	468.9	(AB <sub>2</sub> 'r)
92	Tacloban	11°15'N	21	1737	2210	472	0	27.2	B <sub>1</sub> A'r
93	Cebu City	10°20'N	42	1771	1789	213	194	5.5	C <sub>2</sub> A'r
94	Manila Airport	14°31'N	15	1715	1791	572	497	16.0	C <sub>2</sub> A'w
95	Legaspi City	13°08'N	19	1693	3407	1713	0	101.2	AA'r
96	Cuyo	10°51'N	4	1778	2228	939	491	36.2	B <sub>1</sub> A'w
97	Iloilo City	10°42'N	14	1709	1933	536	311	20.4	B <sub>1</sub> A'w
98	Iwahig	9°44'N	14	1652	1963	556	244	24.8	B <sub>1</sub> A'r
99	Surigao	9°48'N	22	1672	3856	2185	0	130.7	AA'r
100	Dagupan City	16°03'N	2	1821	2002	731	552	22.0	B <sub>1</sub> A'w
101	Zamboanga City	6°58'N	6	1703	1302	0	401	— 14.1	C <sub>1</sub> A'd

No.	Station Name	Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
102	Jolo	6°03'N	13	1671	1987	315	0	18.8	C <sub>2</sub> A'r
103	Davao	7°04'N	20	1689	1971	282	0	16.7	C <sub>2</sub> A'r

Table 7 Moisture Data for BURMA

104	Bhamo	24°16'N	118	1363	1857	692	199	42.0	B <sub>2</sub> A'r
105	Lashio	22°58'N	854	1087	1574	588	99	48.6	(B <sub>2</sub> B <sub>4</sub> 'r)
106	Mandalay	21°59'N	76	1626	776	0	850	— 31.4	DA'd
107	Akyab	20°08'N	5	1491	4778	3606	318	229.1	AA'w
108	Yamethin	20°25'N	119	1581	966	0	616	— 23.4	DA'd
109	Toungoo	18°55'N	48	1564	2105	947	406	45.0	B <sub>2</sub> A'w
110	Victoria Point	9°58'N	47	1720	3964	2653	408	140.0	AA'w
111	Rangoon	16°46'N	23	1693	2529	1409	572	62.9	B <sub>3</sub> A'w <sub>2</sub>
112	Diamond Island	15°51'N	12	1686	3117	1915	483	96.4	B <sub>4</sub> A'w
113	Amherst	16°05'N	22	1655	5156	3983	483	223.2	AA'w
114	Tavoy	14°07'N	6	1618	5856	4714	477	273.7	AA'w
115	Mergui	12°26'N	20	1596	4123	2796	270	165.0	AA'w

Table 8 Moisture Data for PAKISTAN  
(East Pakistan)

116	Satkhira	22°43'N	5	1541	1639	389	292	13.9	C <sub>2</sub> A'w
117	Barisal	22°42'N	3	1513	2065	732	180	41.2	B <sub>2</sub> A'r
118	Srimangai	24°19'N	21	1408	2509	1116	13	78.7	B <sub>3</sub> A'r
119	Narayangani	23°37'N	8	1566	2012	601	154	32.5	B <sub>1</sub> A'r
120	Jessore	23°10'N	7	1500	1608	309	200	12.6	C <sub>2</sub> A'r
121	Chittagong	22°21'N	14	1496	2858	1531	168	95.6	B <sub>4</sub> A'r
122	Cox's Bazar	21°26'N	4	1440	3560	2261	142	151.1	AA'r
123	Dinaj pur	25°38'N	37	1423	1836	646	235	35.5	B <sub>1</sub> A'r
124	Bogra	24°51'N	20	1484	1776	539	247	26.3	B <sub>1</sub> A'r

## (West Pakistan)

No.	Station Name	Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
286	Lahore	31°33'N	214	1396	492	0	— 9036	— 38.8	DA'd
287	Sialkot	32°30'N	253	1355	807	0	— 5480	— 24.3	DA'd
290	Khushab	32°18'N	188	1417	385	0	—10318	— 43.7	EA'd
291	Montgomery	30°40'N	170	1432	257	0	—11753	— 49.2	EA'd
292	Multan	30°12'N	123	1479	167	0	—13117	— 53.2	EA'd
293	Bahawalpur	29°23'N	117	1439	148	0	—12912	— 53.8	EA'd
294	Khanpur	28°39'N	91	1468	165	0	—13025	— 53.3	EA'd
308	Jacobabad	28°18'N	56	1537	990	0	—14379	— 56.1	EA'd
309	Sukkur	27°42'N	67	1522	980	0	—14241	— 56.1	EA'd
310	Hyderabad	25°23'N	29	1616	157	0	—14589	— 54.2	EA'd
311	Karachi (Manora)	24°48'N	4	1503	204	0	—12994	— 51.9	EA'd
312	Badin	24°38'N	9	1554	234	0	—13197	— 51.0	EA'd

Table 9 Moisture Data for INDIA  
(Assam)

125	Dhubri	26°01'N	35	1379	2610	1345	113	92.6	B <sub>4</sub> A'r
126	Tezpur	26°37'N	79	1327	1847	578	59	40.9	B <sub>2</sub> A'r
127	Mohanbari	27°29'N	111	1229	2775	1548	0	126.0	AA'r
128	Gauhati	26°05'N	54	1329	1634	395	91	25.6	B <sub>1</sub> A'r
129	Shillong	25°34'N	1500	802	2252	1452	0	181.1	(AB <sub>2</sub> 'r)
130	Silchar	24°49'N	29	1423	3263	1849	8	129.6	AA'r
131	Cherrapunji	25°15'N	1313	821	11439	10620	0	1294.3	(AB <sub>2</sub> 'r)

## (West Bengal)

132	Port Blair	11°40'N	79	1690	3176	1817	333	95.7	B <sub>4</sub> A'w
133	Saugor (Sagar) Island	21°39'N	3	1544	1803	628	371	26.3	B <sub>1</sub> A'w
134	Car Nicobar	9°10'N	10	1767	2424	874	217	42.1	B <sub>2</sub> A'r

Station		Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
No.	Name								
135	Table Island	14°11'N	27	1731	1941	683	473	23.1	B <sub>1</sub> A'w
136	Calcutta	22°32'N	6	1609	1582	365	393	8.0	C <sub>2</sub> A'w
137	Darjeeling	27°03'N	2127	691	2760	2069	0	299.2	(AB <sub>1</sub> 'r)

## (Orissa)

138	Cuttack	20°48'N	27	1675	1545	412	543	5.1	C <sub>2</sub> A'w
139	Puri	19°48'N	6	1632	1373	226	486	— 4.0	C <sub>1</sub> A'w

## (Bihar)

140	Darbhanga	26°10'N	49	1458	1258	251	449	— 1.3	C <sub>1</sub> A'w
141	Patna	25°37'N	53	1505	1166	231	571	— 7.4	C <sub>1</sub> A'w
142	Gaya	24°45'N	116	1557	1187	267	637	— 7.4	C <sub>1</sub> A'w
143	Dumka	24°16'N	149	1502	1514	414	400	11.6	C <sub>2</sub> A'w
144	Ranchi	23°23'N	655	1294	1513	534	316	26.6	B <sub>1</sub> A'w
145	Daltonganj	24°03'N	221	1448	1237	325	537	0.2	C <sub>2</sub> A'w <sub>2</sub>
146	Jamshedpur	22°49'N	129	1545	1442	360	463	5.3	C <sub>2</sub> A'w

## (Uttar Pradesh)

147	Agra	27°10'N	169	1463	767	0	696	— 28.5	DA'd
148	Kanpur	26°26'N	126	1470	883	84	672	— 21.7	DA'd
149	Allanabad	25°27'N	98	1496	1032	188	653	— 13.6	C <sub>1</sub> A'w
150	Jhansi	25°27'N	251	1526	917	133	742	— 20.5	DA'd
151	Muktesar	29°28'N	2311	706	1308	602	0	85.2	(B <sub>4</sub> B <sub>1</sub> 'r)

## (Madhya Pradesh)

153	Jabalpur	23°10'N	393	1357	1431	567	492	20.0	B <sub>1</sub> A'w <sub>2</sub>
154	Raipur	21°14'N	298	1548	1360	442	630	4.1	C <sub>2</sub> A'w <sub>2</sub>
155	Jagdalpur	19°05'N	553	1393	1530	587	451	22.7	B <sub>1</sub> A'w

Station		Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
No.	Name								
156	Gwalior	26°14'N	207	1455	903	115	669	- 19.7	C <sub>1</sub> A'd
157	Indore	22°43'N	556	1333	1127	309	518	- 13.5	C <sub>1</sub> A'w <sub>2</sub>
265	Sagar	23°51'N	551	1401	1394	6033	6098	17.0	C <sub>2</sub> A'w <sub>2</sub>

## (Andhra Pradesh)

158	Masulipatnam	16°11'N	7	1697	1077	33	652	- 21.1	DA'd
159	Hyderabad	17°27'N	545	1455	761	0	695	- 28.7	DA'd
160	Visakhapatnam	17°43'N	3	1734	944	21	811	- 26.9	DA'd
161	Kakinada	16°57'N	8	1706	1096	26	638	- 20.9	DA'd

## (Madras)

162	Madras	13°00'N	16	1789	1233	275	829	- 12.4	C <sub>1</sub> A's
163	Nagapatlinam	10°46'N	9	1798	1367	450	881	- 4.4	C <sub>1</sub> A's <sub>2</sub>
164	Pamban	9°16'N	11	1808	920	167	1056	- 25.8	DA'd
166	Coimbatore	11°00'N	409	1581	614	0	968	- 36.7	DA'd

## (Mysore)

165	Bangalore	12°58'N	921	1219	924	99	395	- 11.3	C <sub>1</sub> A'd
167	Belgaum	15°51'N	753	1257	1492	701	465	33.6	B <sub>1</sub> A'w <sub>2</sub>
168	Mangalore	12°52'N	22	1709	3479	2367	596	117.6	AA'w <sub>2</sub>
169	Bellary	15°09'N	449	1705	520	1185	0	69.5	B <sub>3</sub> A'r

## (Delhi &amp; Punjab)

152	New Delhi	28°35'N	216	1446	715	0	730	- 30.3	DA'd
262	Simla	31°06'N	2202	710	1542	8320	0	117.2	(AB <sub>1</sub> 'r)
263	Ludhlana	30°56'N	247	1407	725	0	- 682	- 29.1	DA'd
264	Amritsar	31°38'N	234	1316	646	0	670	- 30.5	DA'd

## (Maharashtra)

Station		Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
No.	Name								
275	Bombay (Calaba)	18°54'N	11	1708	2078	12064	8368	41.2	B <sub>2</sub> A'w <sub>2</sub>
276	Ratnagiri	16°59'N	35	1642	2617	17517	— 7769	78.3	B <sub>3</sub> A'w <sub>2</sub>
277	Poona	18°32'N	559	1398	715	0	— 6831	— 29.3	DA'd
278	Sholapur	17°40'N	479	1593	679	0	— 9138	— 34.4	DA'd
279	Aurangabad	19°53'N	581	1457	726	0	— 7306	— 30.1	DA'd
280	Nagpur	21°06'N	310	1554	1251	3179	— 6209	— 3.5	C <sub>1</sub> A'w <sub>2</sub>
281	Akola	20°42'N	282	1602	877	426	— 7674	— 26.1	DA'd

## (Kerala)

284	Fort Cochin	9°58'	3	1705	3106	17460	— 3447	90.3	B <sub>4</sub> A'w
285	Trivandrum	8°29'	64	1708	1835	4610	— 3344	15.2	C <sub>2</sub> A'w

Table 10 Moisture Data for CEYLON

170	Colombo	6°54'N	6	1690	2397	706	0	41.8	B <sub>2</sub> A'r
171	Trincomalee	8°35'N	7	1775	1727	569	617	11.2	C <sub>2</sub> A's <sub>2</sub>
172	Mannar	8°59'N	3	1781	951	106	937	— 25.6	DA'd
173	Hambantota	6°07'N	20	1709	1074	0	637	— 22.4	DA'd
174	Nuwara Eliya	6°58'N	1880	720	2328	1608	0	223.5	(AB <sub>2</sub> 'r)
175	Diyatalawa	6°49'N	1250	919	1671	752	0	81.9	(B <sub>4</sub> B <sub>3</sub> 'r)
176	Badulla	6°59'N	667	1148	1826	731	52	61.0	B <sub>3</sub> A'r
177	Kandy	7°20'N	480	1294	2084	792	0	61.2	B <sub>3</sub> A'r
178	Maha Illuppallama	8°07'N	137	1674	1481	271	464	— 0.4	C <sub>1</sub> A's
179	Kurunegala	7°28'N	116	1687	2158	481	8	28.2	B <sub>1</sub> A'r
180	Anuradnapura	8°21'N	89	1689	1446	289	531	— 1.8	C <sub>1</sub> A's
181	Ratnapura	6°41'N	46	1724	3904	2180	0	126.4	AA'r
182	Ratmalana	6°49'N	5	1709	2479	769	0	45.0	B <sub>2</sub> A'r
183	Galle	6°02'N	18	1636	2422	786	0	48.0	B <sub>2</sub> A'r

No.	Station Name	Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
184	Batticaloa	7°43'N	12	1716	1756	702	661	17.8	C <sub>2</sub> A's <sub>2</sub>
185	Kankesanturai	9°48'N	6	1809	1293	422	938	— 7.8	C <sub>1</sub> A's <sub>2</sub>
186	Jaffna	9°39'N	3	1738	1351	449	834	— 3.0	C <sub>1</sub> A's <sub>2</sub>
187	Puttalam	8°02'N	2	1728	1126	83	684	— 19.0	C <sub>1</sub> A'd

**Table 11** Moisture Data for THAILAND

188	Chiang Rai	19°55'N	378	1393	1747	589	233	32.3	B <sub>1</sub> A'w
189	Mae Hong Son	19°18'N	271	1548	1313	260	495	— 2.4	C <sub>1</sub> A'w
190	Chieng Mai	18°47'N	314	1507	1249	141	399	— 6.5	C <sub>1</sub> A'd
191	Nan	18°47'N	201	1565	1162	115	517	— 12.5	C <sub>1</sub> A'd
192	Lampang	18°12'N	220	1568	1049	0	520	— 19.9	C <sub>1</sub> A'd
193	Phrae	18°10'N	—	1579	1122	43	501	— 16.3	C <sub>1</sub> A'd
194	Mae Sariang	18°10'N	314	1582	1289	221	513	— 5.5	C <sub>1</sub> A'w
195	Uttaradit	17°37'N	63	1683	1496	273	459	— 0.1	C <sub>1</sub> A'w
196	Mae Sot	16°40'N	210	1583	1500	496	580	9.3	C <sub>2</sub> A'w <sub>2</sub>
197	Tak	16°50'N	—	1678	951	0	727	— 26.0	DA'd
198	Loei	17°32'N	—	1487	1194	39	331	— 10.7	C <sub>1</sub> A'd
199	Udon Thani	17°26'N	178	1610	1419	229	420	— 1.4	C <sub>1</sub> A'w
200	Nakhon Phanom	17°30'N	—	1511	2162	1084	435	54.5	B <sub>2</sub> A'w
201	Khon Kaen	16°20'N	157	1638	1210	60	487	— 14.2	C <sub>1</sub> A'd
202	Mukdahan	16°33'N	138	1554	1447	338	445	4.6	C <sub>2</sub> A'w
203	Roi Et	16°03'N	140	1644	1414	254	482	— 2.1	C <sub>1</sub> A'w
204	Chaiyaphum	15°45'N	—	1634	1089	31	577	— 19.3	C <sub>1</sub> A'd
205	Ubon Ratchathani	15°15'N	123	1657	1531	358	485	4.0	C <sub>2</sub> A'w
206	Nakhon Ratchasima	14°58'N	181	1657	1156	20	521	— 17.7	C <sub>1</sub> A'd
207	Surin	14°53'N	145	1654	1341	134	448	— 8.1	C <sub>1</sub> A'd
208	Phitsanulok	16°50'N	50	1761	1356	127	533	— 10.9	C <sub>1</sub> A'd
209	Phetchabun	16°25'N	114	1622	1288	137	470	— 8.9	C <sub>1</sub> A'd

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Station		Latitude	Altitude m	Water need (PE or TE)	Precipitation	Water surplus	Water deficiency	Moisture index (Im)	Climatic type
No.	Name								
210	Nakhon Sawan	15°48'N	28	1794	1182	33	644	- 19.7	C <sub>1</sub> A'd
211	Lop Buri	14°48'N	13	1797	1239	43	600	- 17.6	C <sub>1</sub> A'd
212	Suphan Buri	14°30'N	—	1785	1279	109	617	- 14.6	C <sub>1</sub> A'd
213	Kanchanaburi	14°01'N	28	1741	992	0	749	- 25.8	DA'd
214	Don Muang	13°55'N	3	1824	1544	224	504	- 4.3	C <sub>1</sub> A'w
215	Bangkok	13°44'N	—	1806	1409	184	522	- 7.2	C <sub>1</sub> A'w
216	Prachin Buri	14°10'N	—	1773	2112	802	465	29.5	B <sub>1</sub> A'w
217	Aranyaprathet	13°42'N	44	1738	1522	177	394	- 3.4	C <sub>1</sub> A'w
218	Sattahip	12°39'N	55	1906	1313	100	691	- 16.5	C <sub>1</sub> A'd
219	Chanthaburi	12°37'N	5	1719	3027	1647	338	84.0	B <sub>4</sub> A'w
220	Khlung Yai	11°47'N	4	1691	4456	2964	199	168.3	AA'r
221	Hua Hin	12°34'N	3	1730	1019	31	742	- 23.9	DA'd
222	Prachuap Khiri Khan	11°48'N	5	1681	1163	54	572	- 17.2	C <sub>1</sub> A'd
223	Chumphon	10°27'N	3	1650	1964	400	84	21.2	B <sub>1</sub> A'r
224	Ban Dan	9°08'N	3	1725	1858	384	251	13.5	C <sub>2</sub> A'r
225	Nakhonsithammarat	8°25'N	5	1727	2569	941	99	51.0	B <sub>2</sub> A'r
226	Songkhla	7°13'N	4	1789	2232	858	416	34.0	B <sub>1</sub> A's
227	Narathiwat	6°26'N	4	1671	2690	1076	58	62.3	B <sub>3</sub> A'r
228	Ranong	9°58'N	35	1631	5107	3695	218	218.5	AA'r
229	Phuket	7°58'N	3	1775	2389	888	274	40.8	B <sub>2</sub> A'r
230	Trang	7°30'N	—	1755	2178	661	238	29.5	B <sub>1</sub> A'r